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GOLD PLATED LEAD-CLINCHED LEAD SOLDER JOINT STUDY.(U)
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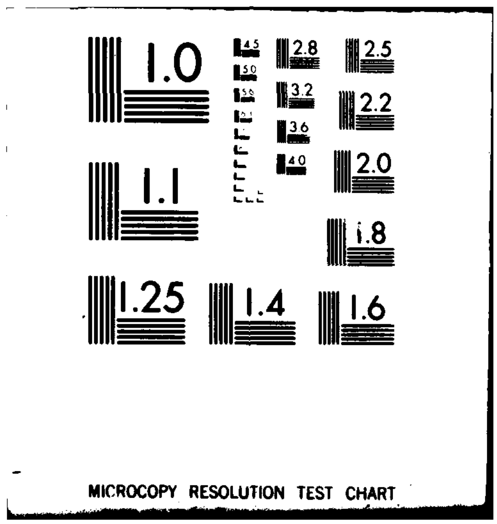
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TECHNICAL REPORT E-79-29

GOLD PLATED LEAD-CLINCHED LEAD SOLDER JOINT STUDY

Roger L. Yocom
Engineering Laboratory

September 1979

U.S. ARMY MISSILE COMMAND
Redstone Arsenal, Alabama 35809

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In this study the affects of soldering to gold-plated lead wires as opposed to soldering to pretinned or double-tin dipped lead wires are investigated. Also investigated were the differences between Types I, II, and III lead termination methods as described in MIL-P-46843, Paragraphs 3.6.4.3.7, 3.6.4.3.8, and 3.6.4.3.9 respectively.

Data generated may be utilized in the design of printed circuit boards, the revision of soldering and component specifications, and for decision criteria upon which engineering changes may be evaluated.

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CONTENTS

ILLUSTRATIONS

1. INTRODUCTION

This project concerns itself with the study of soldered electrical connections, in particular the characteristics of lead wires soldered into plated-through holes in printed wiring boards. Specific items under investigation were the effects of soldering to gold plated lead wires and the differences between clinched, 45° bend, and straight-through lead termination methods (Types I, II, and III as described in MIL-P-46843, paragraphs 3.6.4.3.7, 3.6.4.3.8, and 3.6.4.3.9 respectively.

The purpose of this Technical Report is to publicize the highly significant data trends which have been observed. The data support the following: pretinned or double-tin dipped lead wires appear to be two to eight times more reliable than gold plated lead wires, and clinched lead terminations (Type I) appear to be five to twenty-five times more reliable than straight lead terminations (Type III). Although based upon a limited data base, these trends are quite clear. Further testing should be performed to statistically validate these trends and to define the mechanisms controlling the observed effects.

2. BACKGROUND

Weapons systems contractors have requested waivers, deviations, and engineering changes to the specification requirements related to gold plated lead wires and lead termination methods. Some contractors are of the opinion that advances in the art and technology of soldering have negated the benefits of these specification requirements. They have stated that properly soldered straight through (unclinched) leads are as strong or stronger than clinched lead joints and that, using modern soldering techniques, gold plated lead solder joints are not significantly different from solder joints involving gold plated lead wires that have been double-tin dipped prior to soldering. These opinions are supported by undocumented theory and/or experience, whereas the contrary has been shown to be true by documentd data. [1,2,3]. This documented data should end the debate. However, a careful study of the past experimental data reveals that it was usually taken on nonplated through hole joint configurations and/or was not done using modern machine soldering techniques.

If the present state-of-the-art has improved the solder joint significantly, then present specification requirements may result in needless expense during the production process. In reality, technological advances may have negated the benefits derived from these specification requirements.

3. DESCRIPTION OF TEST SAMPLES

Over five hundred printed circuit board test samples were produced. Each board is two inches wide and thirteen inches long with fifty solder joints of the general configuration shown in *Figure 1*.

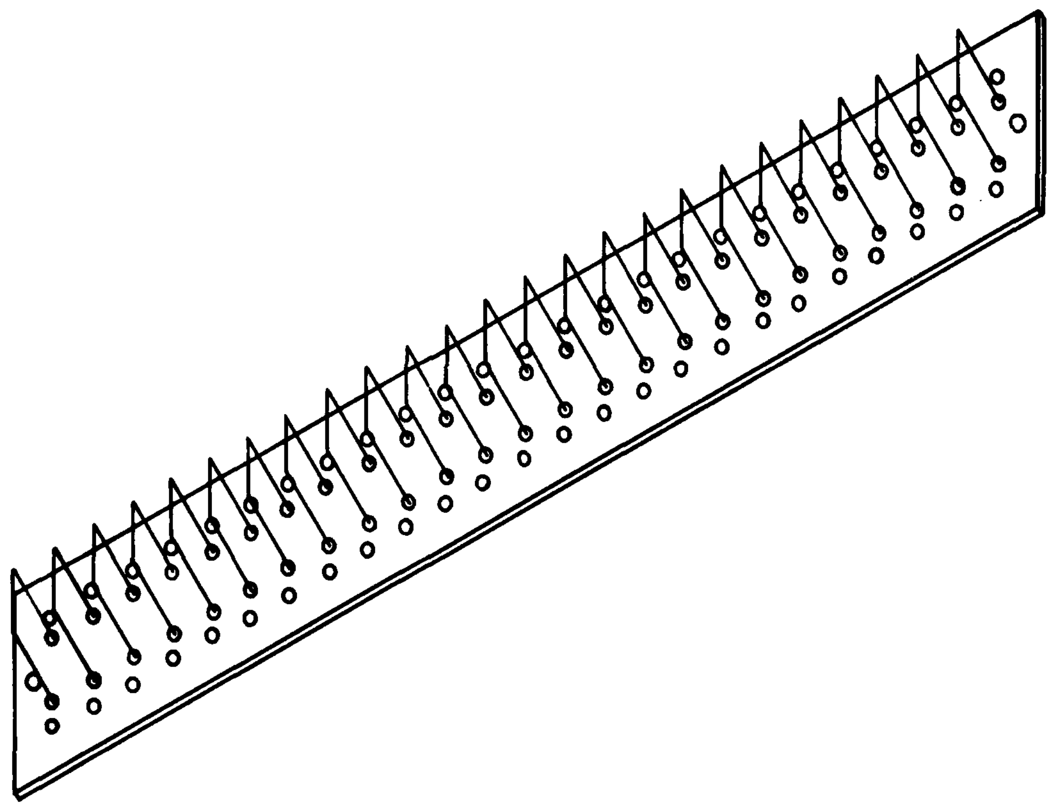

Figure 1. Schematic of a test board.

Approximately 200 different solder joint configurations and/or histories were represented. The controllable variations under investigation included:

- Gold plating thickness - six different thicknesses.
- Lead wire preparation - gold plated no pretinning vs gold plated double-tin dipped vs pretinned.
- Lead wire (Diameter) - .48 mm vs .63 mm (0.019-in. vs 0.025-in.).
- Printed circuit board thickness - .254 mm vs 1.57 mm (.010-in. vs .062-in.).
- Lead termination method - Type I (Clinched lead) vs Type II (45° Bend) vs Type III (Straight through) (See *Figure 2*).
- Soldering method - hand soldering vs machine soldering.
- Temperature cycling - 0 cycles vs 300 cycles vs 1000 cycles.

4. AGING TESTS

An aging study was conducted in order to:

- Determine the effects of gold plating on the aging properties of solder joints.
- Determine whether aging curves for the test samples resemble those found by previous investigations. [4]
- Determine when the joints have aged sufficiently to permit the performance of additional tests without having solder aging being a significant variable.

During the aging study 1000-1100 solder joints from thirty different sample boards were pull tested. The solder joints were made with .48 mm kovar wire, straight through Type III lead termination, and wave soldered, into plated through holes in 1.57 mm fiberglass printed circuit boards. The lead wires were in one of the following six conditions prior to soldering:

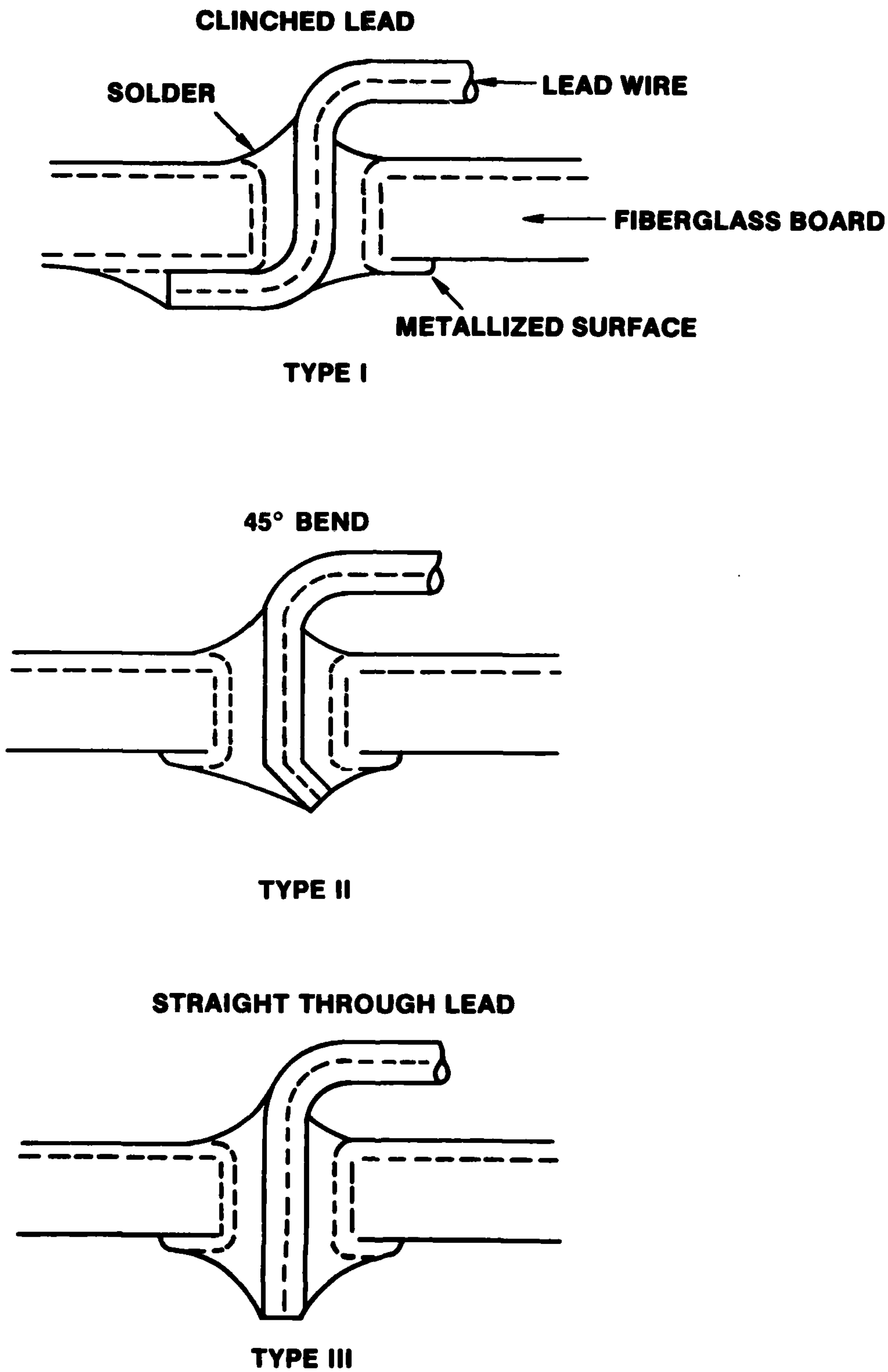

Figure 2. Lead termination methods which are under investigation.

- Gold plated with 7.65 micrometers of gold and no pretinning prior to soldering.

- Gold plated with 7.65 micrometers of gold and then double-tin dipped prior to soldering.

- Gold plated with 2.55 micrometers of gold and no pretinning prior to soldering.

- Gold plated with 2.55 micrometers of gold and double-tin dipped prior to soldering.

- Solder plated and no pretinning prior to soldering.

- Solder plated and double-tin dipped prior to soldering.

Joints from each of these six data sets were tested (using the pull testing device shown in *Figure 3*) on the day soldered and periodically thereafter. Due to the breakdown and reworking of test equipment, aging tests run during the first twenty-five days were of a different statistical grouping than those run later in the program.

Figure 4 displays the averages of the data taken during the first 25 days after the various test samples had been soldered. Gold plating did appear to have an affect on the solder joint strengths; however, the true nature of its affect could not be determined due to variablility of the data. The aging curves were similar to those found by Lampe.[4] The time necessary for the solder joints to age and obtain a steady state was approximately three to six weeks as in Lampe's test.

All solder joints were given six to eight weeks to age prior to performing nonaging tests. Aging was assumed not to be an influencing factor during the testing that followed.

5. TENSILE TESTS

It is documented that gold affects the properties of solder if it is present in sufficient quantity. [1,2,3] Gold embrittlement has been diagnosed as the cause of solder joint failure. [1,2,3,5,6]. Some pseudo authorities think that the pretinning of gold plated leads should be eliminated. They say that modern wave soldering processes wash the gold off the lead wire and disperse it into the bulk of the solder. Therefore, the gold will not affect the finished solder joint. A series of tensile tests were performed to determine if the physical property of a solder joint is affected by a gold plated lead wire.

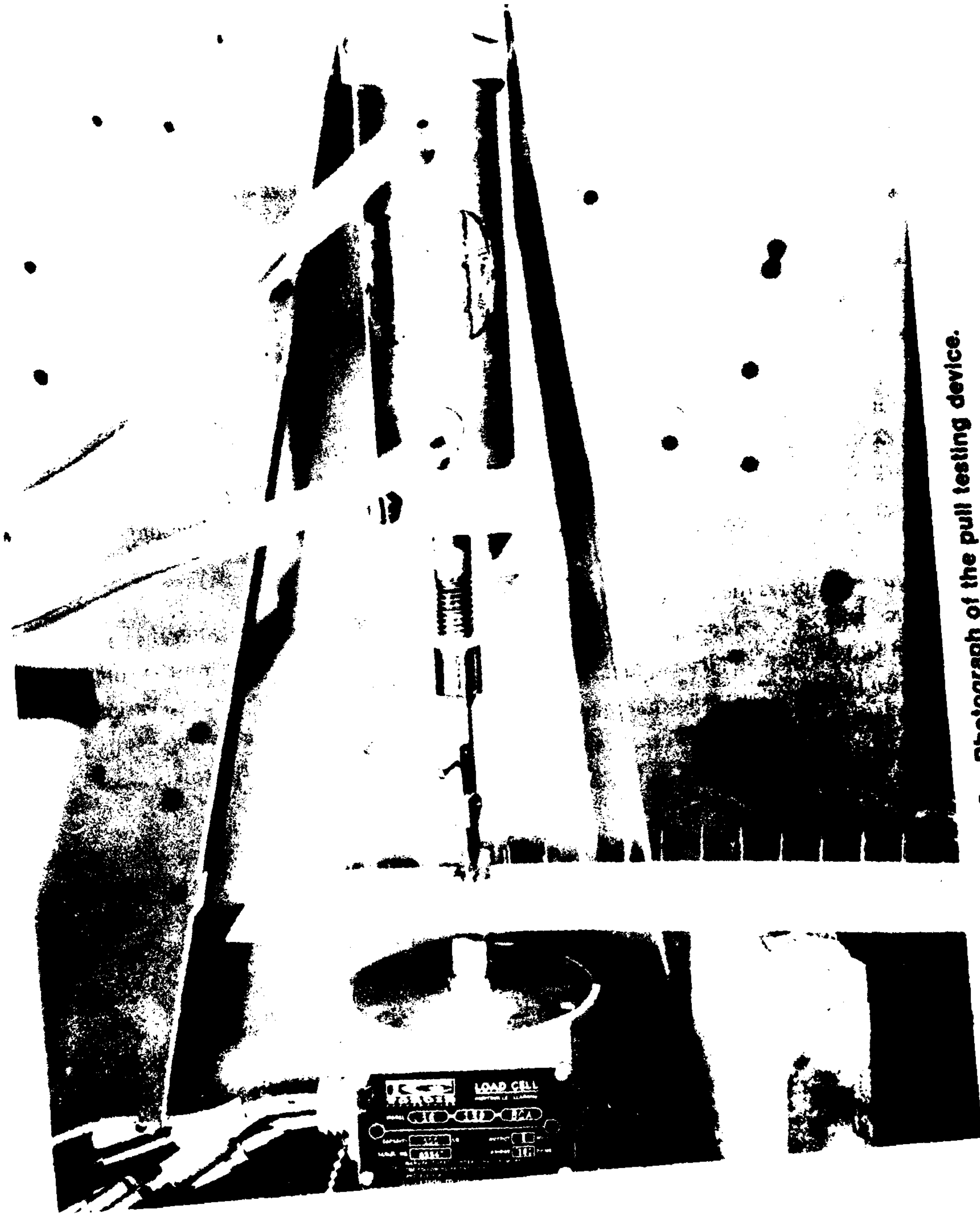

Figure 3. Photograph of the pull testing device.

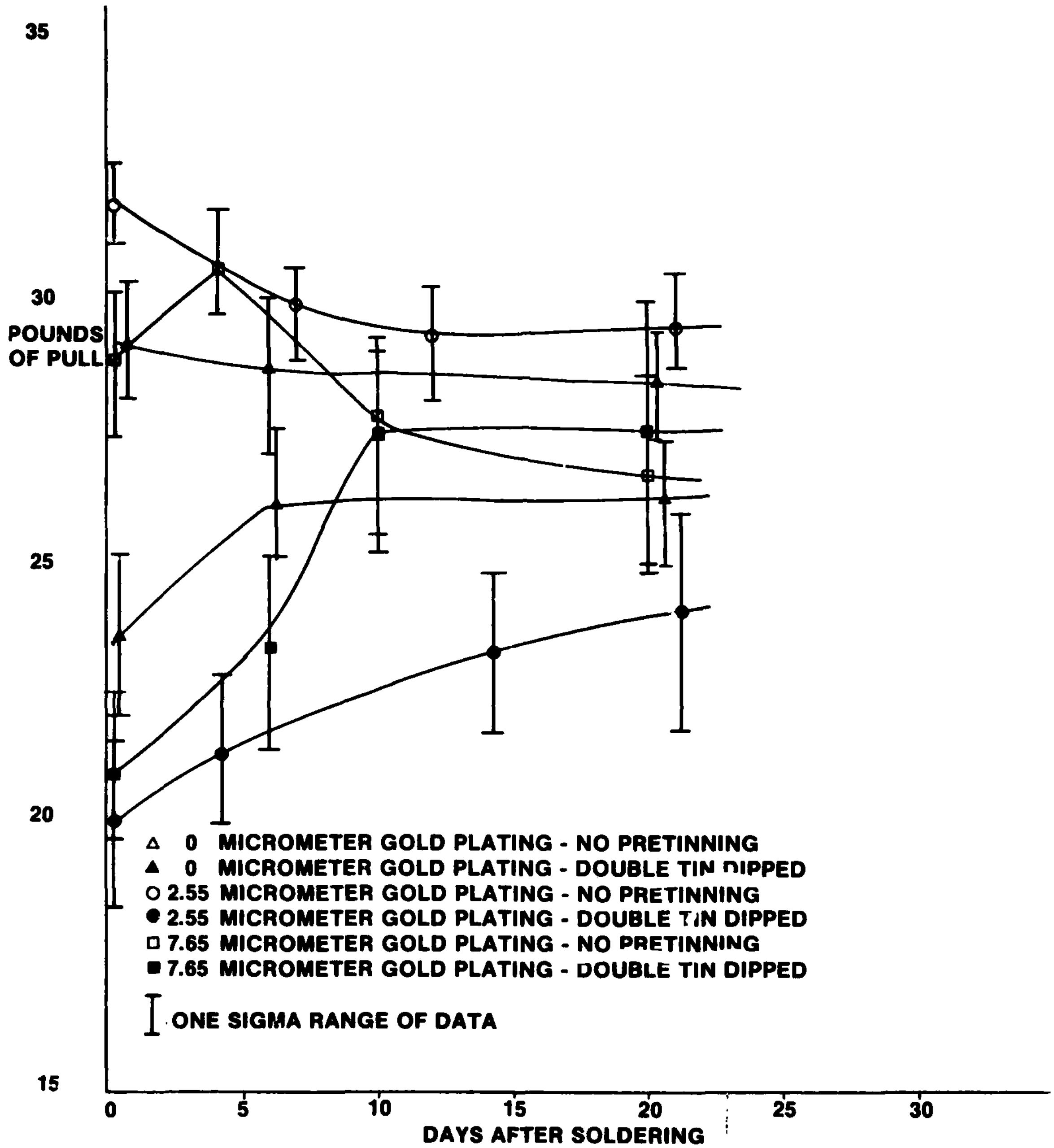

Figure 4. Aging test data.

Seven test boards were used in this study testing approximately 250 solder joints. All solder joints were 0.48 mm kovar wire, straight through, Type III lead termination, and wave soldered into plated through holes in a 1.57 mm fiberglass printed circuit board.

The lead wires were not pretinned (double-tin dipped) prior to soldering. The condition of each board differed as follows:

- Soldered plated.
- Gold plated with 0.60 micrometers (25 microinches) gold.
- Gold plated with 1.25 micrometers (50 microinches) gold.
- Gold plated with 1.90 micrometers (75 microinches) gold.
- Gold plated with 2.55 micrometers (100 microinches) gold.
- Gold plated with 5.10 micrometers (200 microinches) gold.
- Gold plated with 7.65 micrometers (300 microinches) gold.

The results of this testing are shown in *Figure 5*.

The standard deviation of the tensile strength for solder joints made with solder plated (0.0 micrometer gold plating) lead wires was 0.29 kilograms. It should be noted that the average tensile strengths for solder joints made using lead wires with greater than 1.25 micrometers (50 microinches) gold plating were greater than one standard deviation (0.29 kilograms) from the reading for solder plated lead wires (12.07 kilograms). Although this test does not show what magnitude of affect gold plated lead wires have on the failure mode in storage, the testing does prove that gold plating on lead wires does affect the ultimate solder joint qualities, and it is generally accepted that gold contamination is not good for solder joints.

6. CREEP TESTS

The term creep testing as utilized in this report refers to a test in which a known static load is placed on a soldered lead wire and the time to failure is measured (failure being designated by the wire disengaging from the printed circuit board). Applying small pressures for extended periods of time is one of the most common failure modes of solder joints. [6-11] These

MICROMETERS OF GOLD PLATING	MICROINCHES OF GOLD PLATING	AVERAGE TENSILE STRENGTH IN KILOGRAMS	DIFFERENCE BETWEEN 0.0 MICROMETERS GOLD AVERAGE TENSILE STRENGTH AND AVERAGE TENSILE STRENGTH OF GOLD PLATED LEAD SOLDER JOINT IN KILOGRAMS
0.0	0	12.07	0
0.60	25	11.88	-0.24
1.25	50	11.96	-0.12
1.90	75	11.65	-0.42
2.55	100	11.72	-0.35
5.10	200	12.57	+ .49
7.65	300	13.65	+1.58

Figure 5. Summary of results of tensile tests.

pressures are most often caused by residual stresses built in during soldering or the difference between the thermal expansion coefficients of the various materials. It can be calculated that in some common configurations as much as 1 kilogram pressure is placed in each lead wire of a component for every 15 - 30 degree centigrade temperature rise. [11] Creep testing is an attempt to simulate these failure mode conditions as accurately as possible while constrained by test sample configuration and timeliness. The test setup used is graphically depicted in *Figure 6*.

The first two configurations studied using a creep testing mode had solder joints made with 0.48 mm kovar wire, straight through (Type III) lead terminations, and wave soldered into plated-through holes in a 1.57 mm fiberglass printed circuit board. One test board had lead wires with 7.65 micrometers of gold plating prior to soldering. The other board had lead wires with 7.65 micrometers of gold plating and lead wires double-tin dipped prior to soldering. These solder joints were tested utilizing dead weights ranging from 7 kilograms to slightly over 11 kilograms. At each weight tested a five point statistical sample was taken.

The results of this testing are plotted in *Figure 7*. When creep tested at high pressures, there is minimal difference in the time to failure; however, at 7 kilograms the average time to failure is approximately twice as long for double-tin dipped lead wires as it is for gold plated nonpretinned lead wires. It may be noted that the time to failure approximates a linear function on semilogarithmic graph paper as one might predict from Andrade's Creep Law.

Andrade's Creep Law

Creep, which may be defined as plastic flow under constant stress, depends upon the time of application of the stress;

$$\gamma = At^n$$

where γ is the strain, A and n are constants and $0<n<1$. Where $n = 1$ we obtain the logarithmic creep law:

$$\gamma = \alpha \log t$$

which has been observed for rubber, glass and various metals.

If this linearity continues, one kilogram load a double-tin dipped gold plated lead would be predicted to last six to seven times as long as nonpretinned gold plated lead.

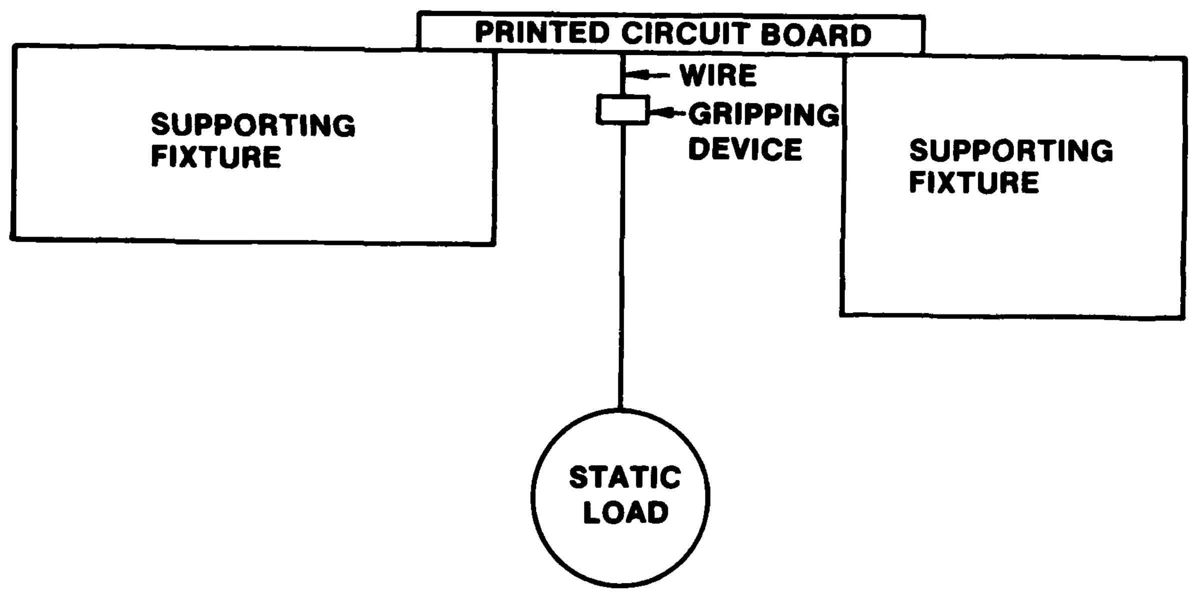

Figure 6. Schematic of test setup for creep testing.

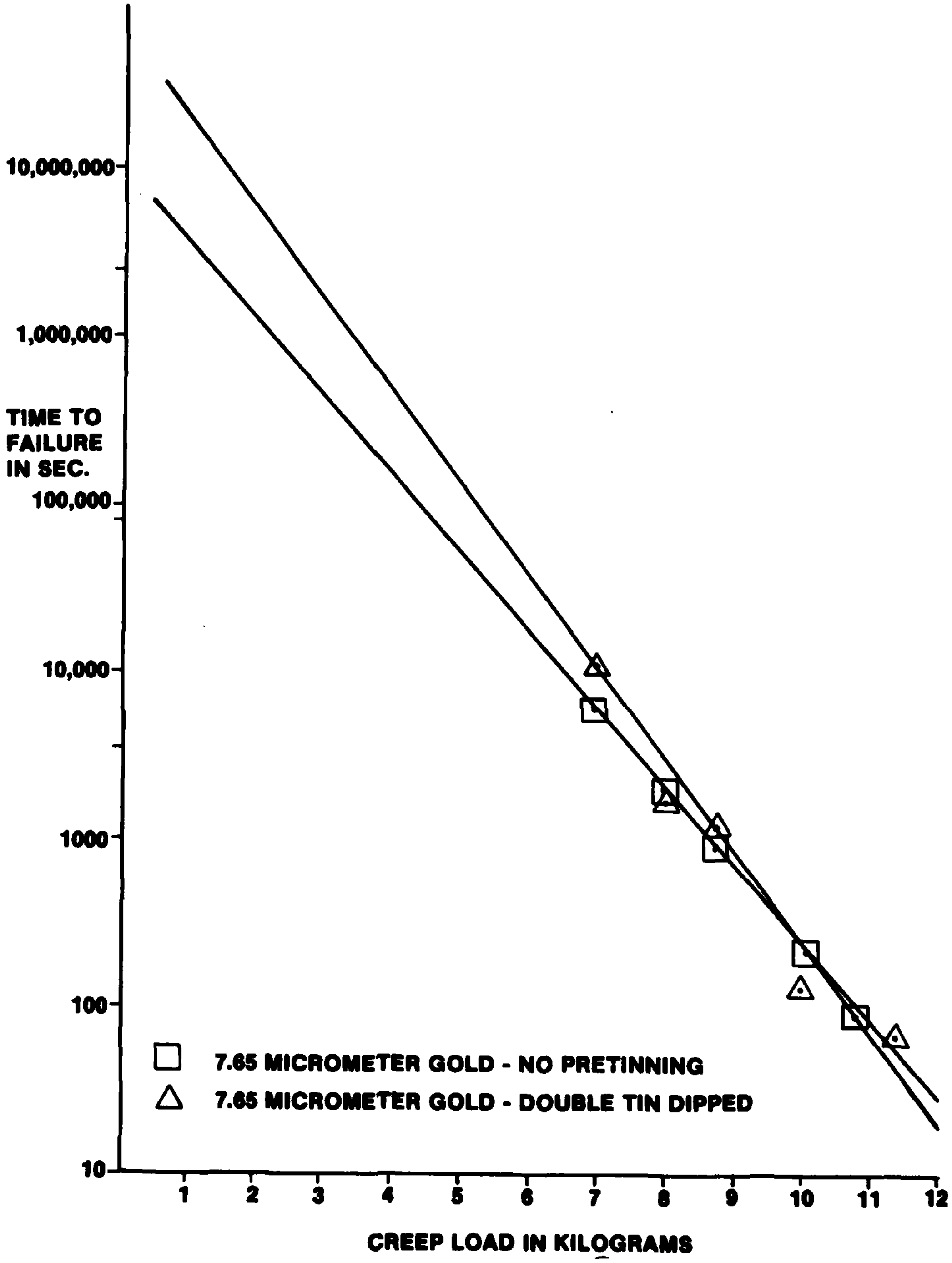

Figure 7. Results of 1.57 millimeter printed circuit board creep test.

The next series of creep tests were done on samples similar to the first two samples, except that the fiberglass boards were 0.254 mm thick rather than 1.57 mm as in the first set of tests. This provided the opportunity to study several items. First, tests could be run at lower weights without time frames being as prohibitive. Second, the affects of using gold plated leads on thick versus thin boards could be observed. Third, the prediction that pretinned leads lasts six to seven times as long as nonpretinned leads at 1 kilogram pressure could be tested. Lastly, linearity of the relationship could be observed to determine if it breaks down and an asymptotic nature takes over. The results of this testing are plotted in *Figure 8*.

It should be noted that the data points for 2 - 5 kilograms are 5 point statistics; the data for the 1 kilogram loads are only 3 point statistics; and the data for 1 kilogram 7.65 gold plated double-tin dipped is only a minimum average. (Only one of the three joints under test failed at the time this report was written. This average may be significantly increased before all three joints fail.)

Based upon these results it is apparent that, within the printed circuit board thickness range tested, gold plated lead solder joints are not as good as double-tin dipped lead solder joints regardless of the printed circuit board thickness. On thin boards at 1 kilogram, the double-tin dipped lead solder joints lasted at least six times as long as the gold plated leads. The semilogarithmic graph of the creep function remains linear down to approximately two kilograms then approaches zero asymptotically.

The third series of creep tests involved the testing of solder joints with Type I, clinched lead, termination versus Type III, straight through lead, termination utilizing solder plated lead wires. The results of this testing are plotted in *Figure 9*. All data points on *Figure 9* are based upon 5 point statistics. The clinched lead data plotted in *Figure 9* is distinctively nonlinear and have a greater average time to failure than straight through leads. It was also observed that the curve for the clinched lead data predicts an approach to an asymptote between 2 and 4 kilograms. This may be related to the modulus of bending of the kovar wire.

7. CONCLUSIONS

Double-tin dipped lead wires create solder joints with a 2 - 8 times longer life expectancy than gold plated lead wires that are not pretinned. Clinched leads have a life expectancy 5 - 25 times that of a straight through lead. In both cases the amount of additional life expectancy is dependent upon the pressure involved. The lower the pressure the greater the benefit.

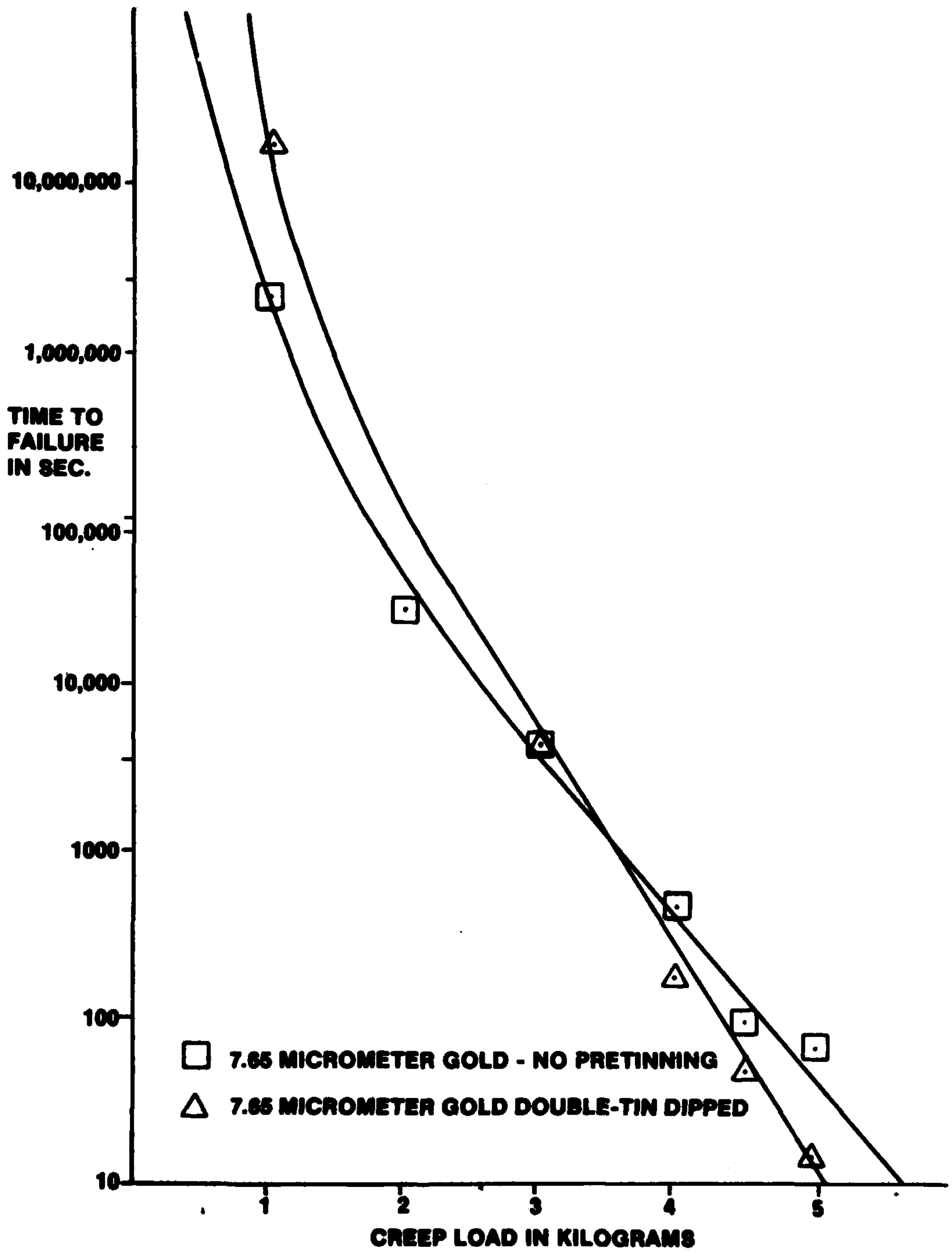

Figure 8. Results of 0.254 millimeter printed circuit board creep test.

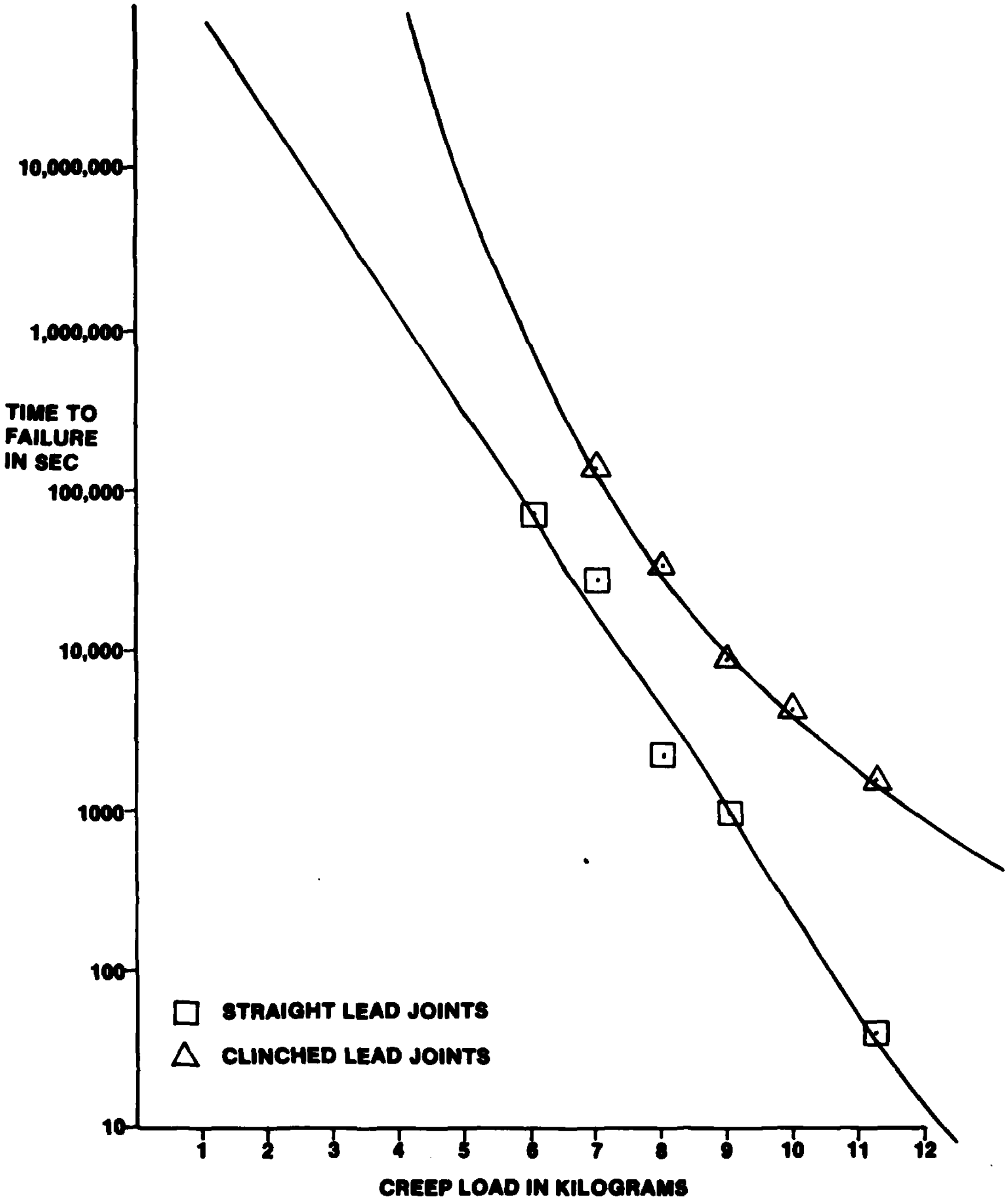

Figure 9. Results of 1.57 millimeter printed circuit board clinched lead versus straight lead creep test.

The soldering specification requirements and recommendations appear to be very valid in these two instances. The results of the testing have proven that even with the use of modern wave soldering techniques, the theories upon which these soldering specification callouts were founded are still valid.

8. RECOMMENDATIONS

There should be further work done in the areas which have been tested during this study. More data should be taken in order for more statistical comparisons to be made. The angle of clinching necessary to obtain the benefits of a clinched lead should be investigated. It should be determined whether or not there is a thickness of gold plating below which a solder joint will not be adversely affected.

It is further recommended that a metallographic and scanning electron microscopic study be made in conjunction with the gold plating studies to reveal the metallurgic and microcompositional effects of soldering to gold plated lead wires. There is also a need to study the differences between machine-soldered and hand-soldered joints in relation to the effects of gold plating and lead clinching.

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DRCPM-CFT, Mr. Wallace	1
-HD	1
-PE, Mr. Greenland	1
Mr. Keeling	1
-DTQ	1
-RST	1
-HEL	1
-ROL	1
-VIT	1
-HA, Mr. Sutton	1
-LC	1
-MP	1
DRSMI-LP, Mr. Voigt	1
-EX, Mr. Owen	1
-O	1
-V	1
-R	1
-UH	1
-UL	1
-US	1
-UR	1
-I, Mr. Vickers	1
-ET, Mr. Woodham	1
-EM, Mr. Yocom	50
-ED, Mr. Holloway	1
-Q, Mr. Lamm	1
Mr. Hill	1
Mr. Porter	1
Mr. Wenslaski	1
-RPR	3
-RPT	2
-RT, Mr. Wheat	1

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